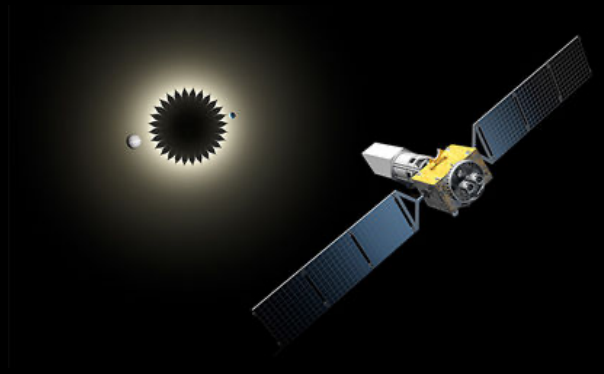
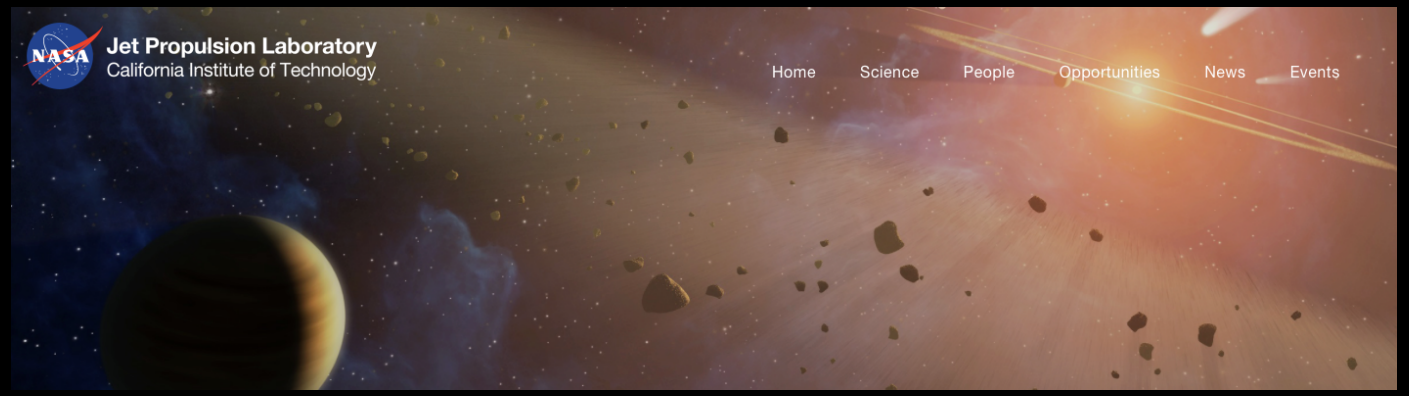
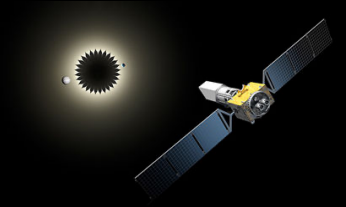
SISTER: Imaging Exoplanets with Starshade

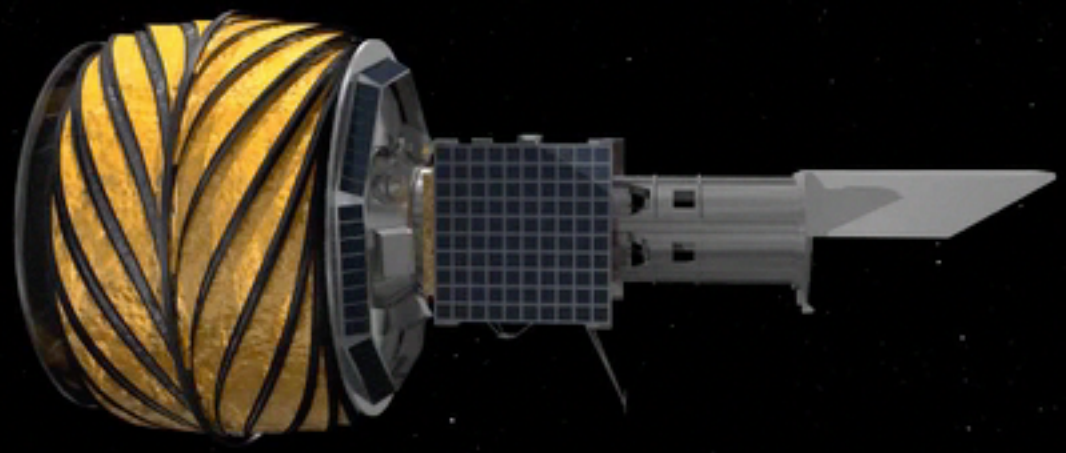




Sergi R. Hildebrandt, JPL/Caltech

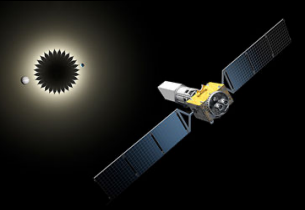
Starshade in a movie





Jet Propulsion Laboratory
California Institute of Technology

Starshade Fundamentals

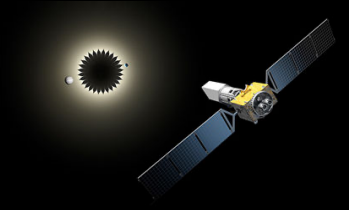


The starshade blocks the on-axis starlight before it enters the telescope, while still allowing the light from the planets to enter.

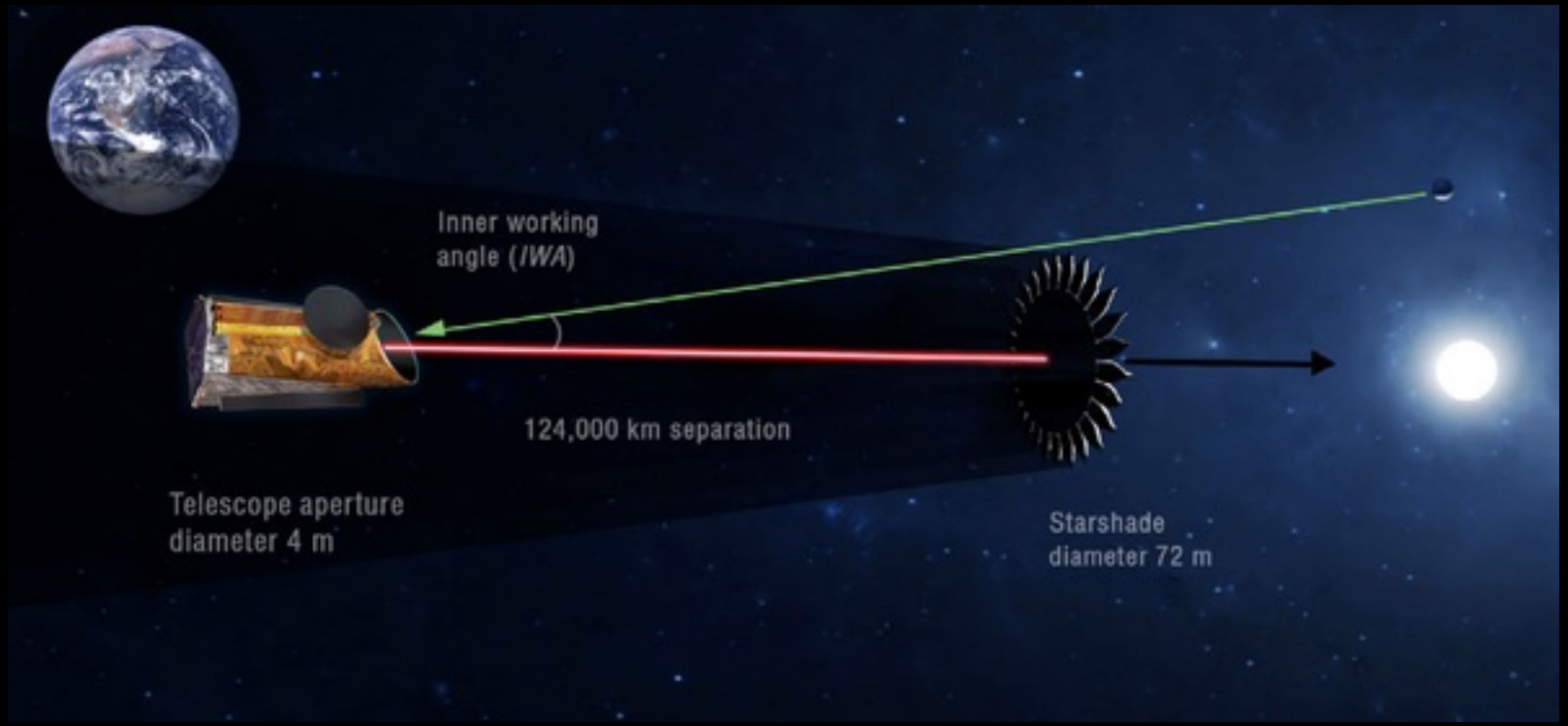
A starshade does not require the need for extreme diffraction and wavefront control from the observatory, as coronagraphs do, but it has to be realigned for every target, and has to keep the formation flight to within few mas.

Starshade techonology development is making great progress.

Starshade geometry

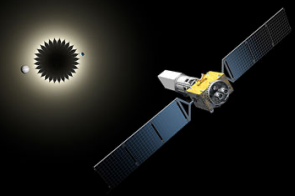


Habitable Exoplanet Observatory (HabEx)

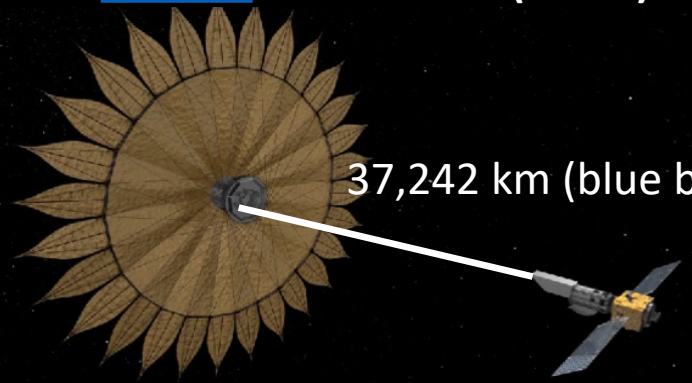


Starshade diameter on this picture is only **120** mas as seen from the telescope.
Same angular size as Mercury semi-major axis at 10 light years.

Starshade: Mission Studies

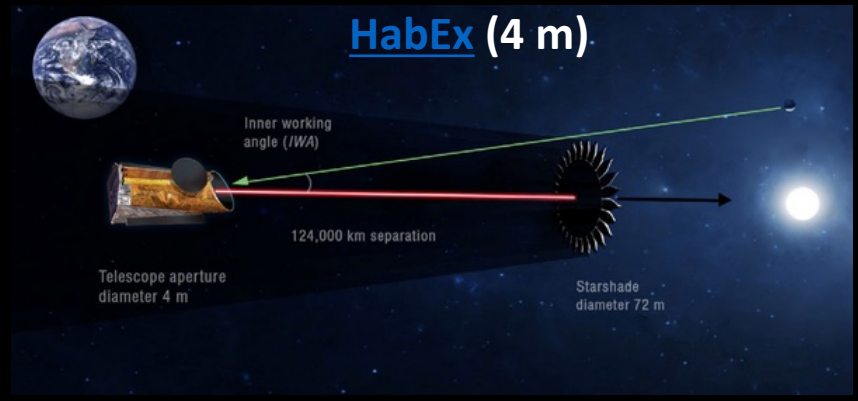


WFIRST Rendezvous (2.4 m)

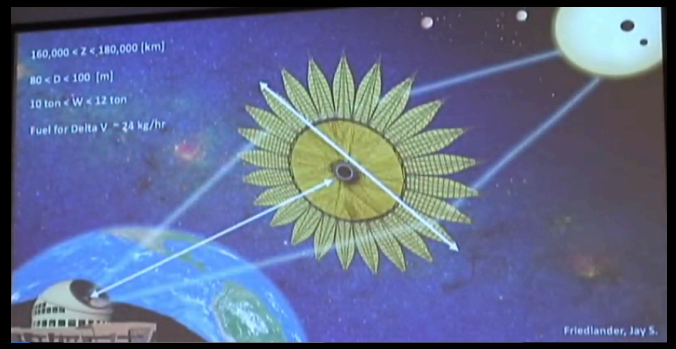


Not to scale

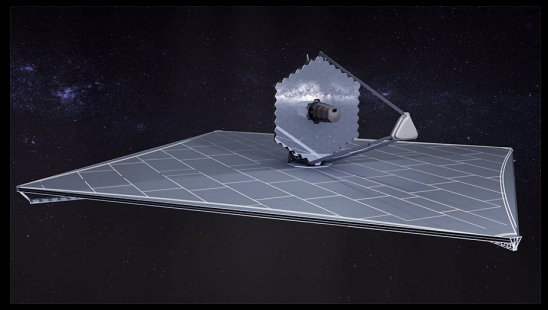
HabEx (4 m)



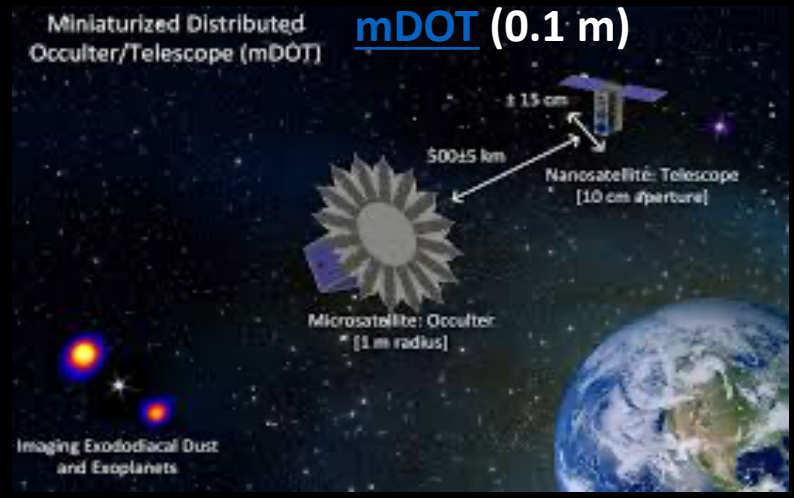
Ground telescopes (30-40 m)



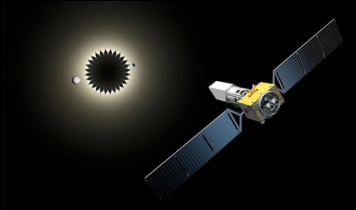
LUVOIR B (8 m)



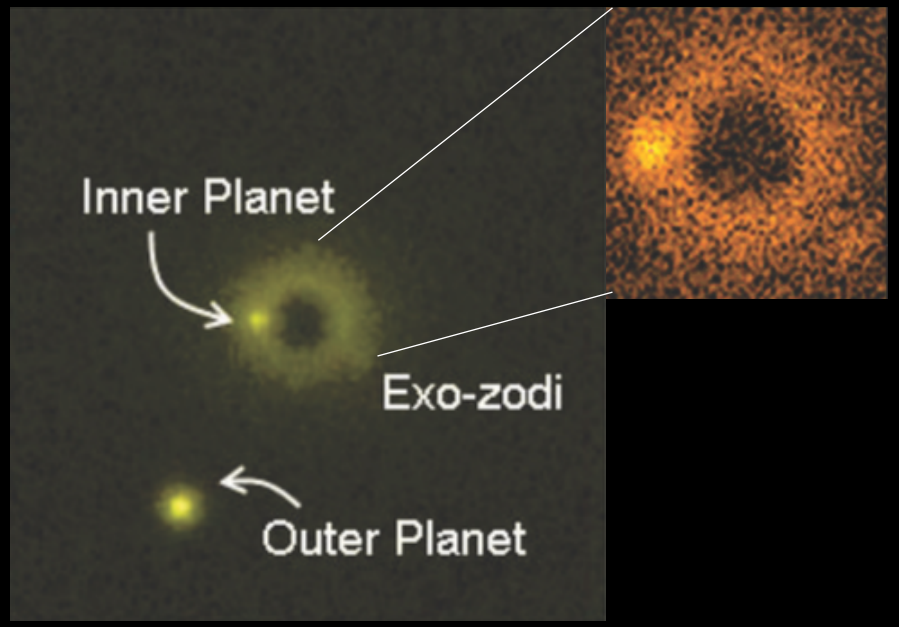
mDOT (0.1 m)



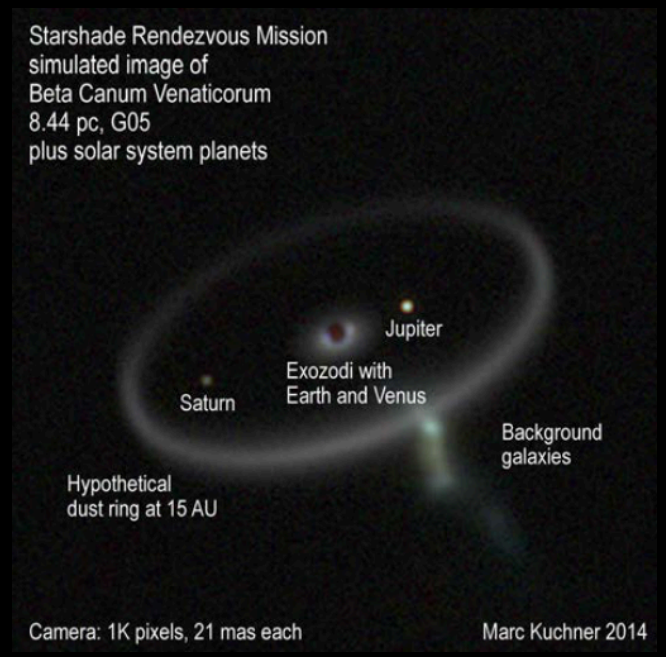
Starshade: Simulations



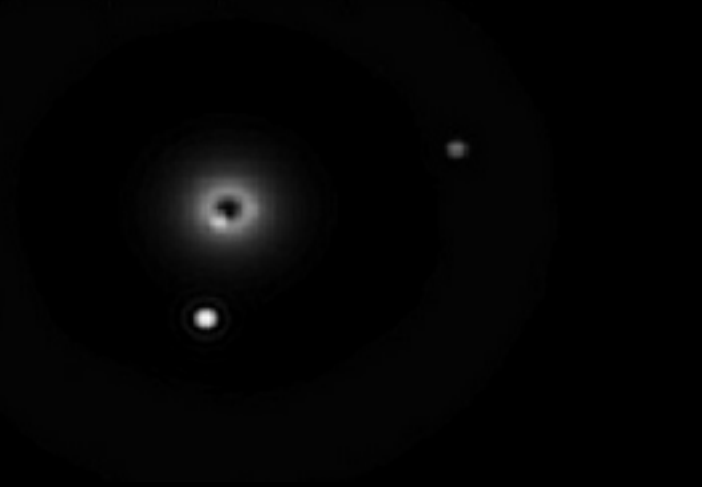
A few, specific examples. No general user interface.



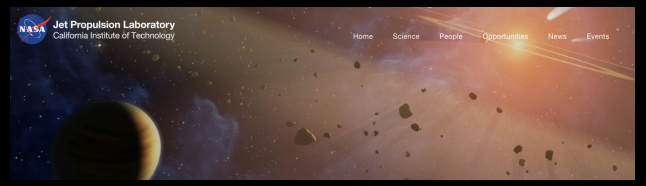
[Lillie et al. SPIE News 2008]



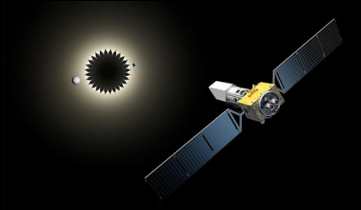
[Exo-S Mission Study 2014]



[M. Hu,, A. Harness,,and N. J. Kasdin SPIE 2017]



SISTER



SISTER (Starshade Imaging Simulation Toolkit for Exoplanet Reconnaissance) is a versatile tool designed to provide enough accuracy and variety of Starshade astrophysical simulations.*

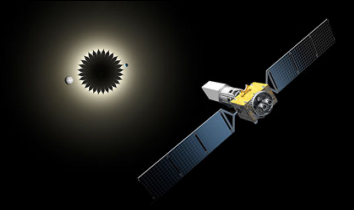
It allows for controlling a set of parameters of the whole instrument that have to do with: (1) the Starshade design, (2) the exoplanetary system, (3) the optical system (telescope) and (4) the detector (camera).

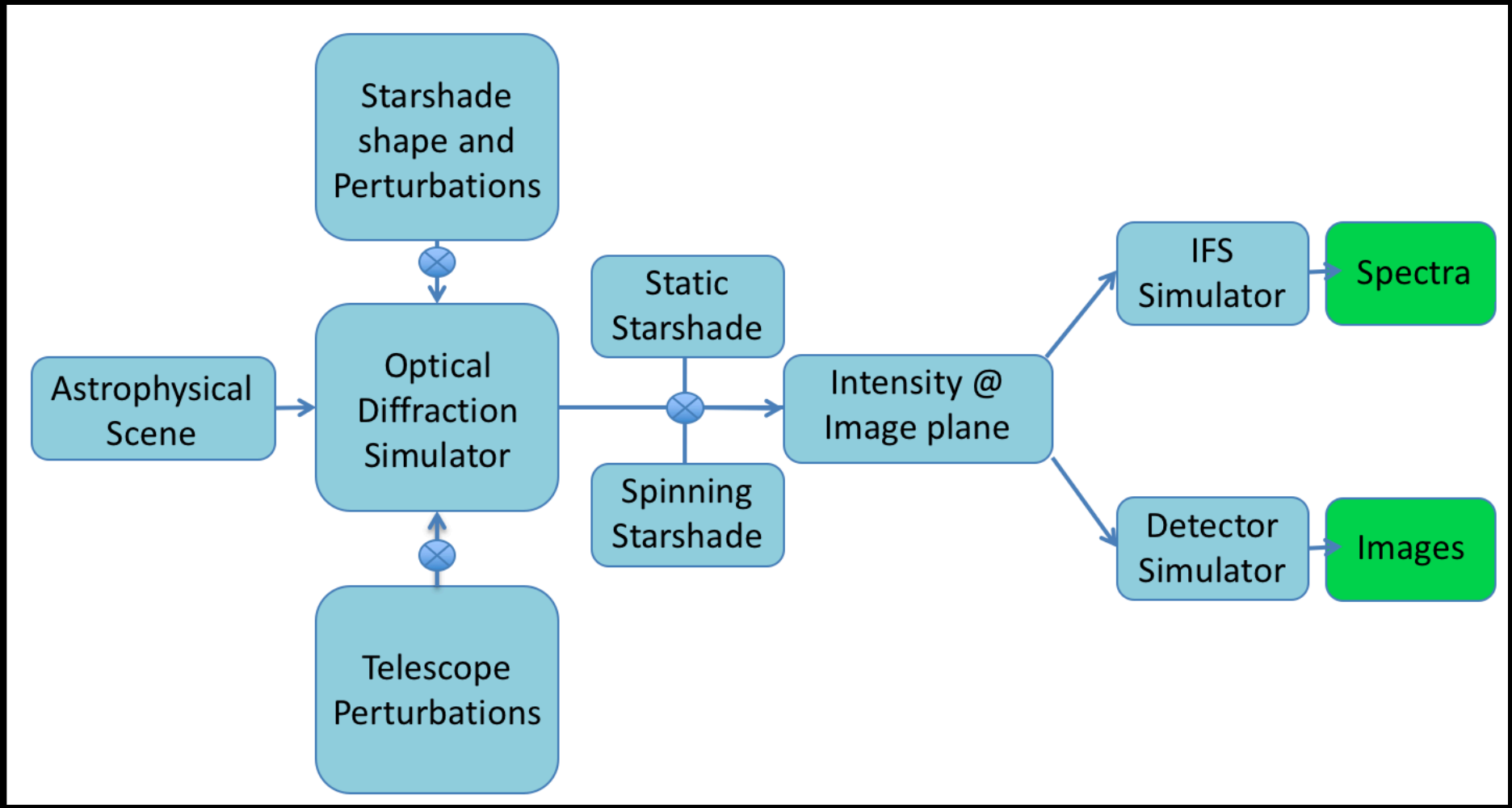
There is a built-in plotting software added, but the simulations may be stored on disk and plotted with any other software.

SISTER is an open source project that will evolve with Starshade.

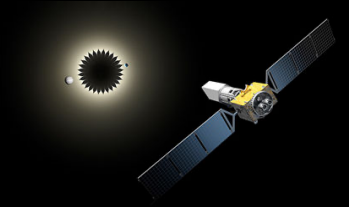
(*) S.R. Hildebrandt[1] (srh@caltech.edu), S.B. Shaklan[1], E.J. Cady[1], and M.C. Turnbull[2]. (1) Jet Propulsion Laboratory & California Institute of Technology Pasadena, California (2) SETI Institute, Carl Sagan Center for Life in the Universe

SISTER Cartoon



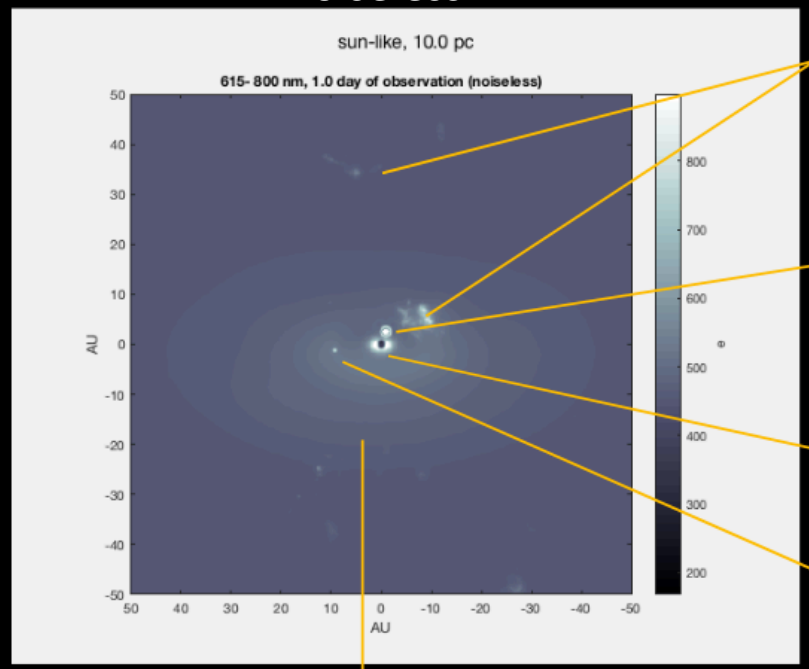


SISTER Example



Example: solar System[1] at 10 pc with WFIRST (60° inclination. Processed with SISTER)

Noiseless



5''

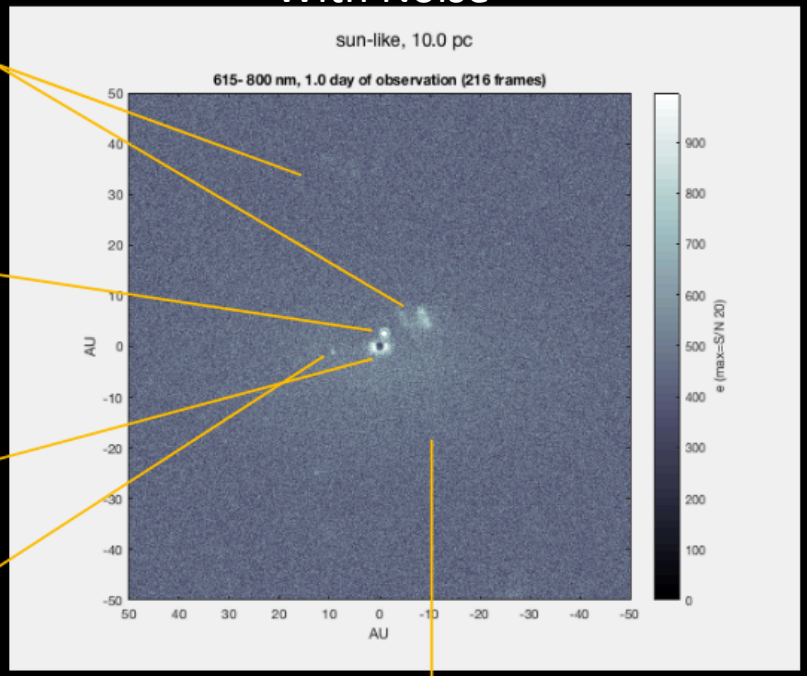
Background objects

Jupiter

Blocked Star

Saturn

With Noise

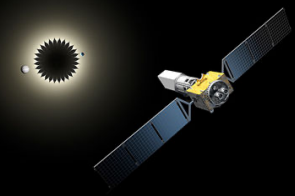


Exo-zodiacal light (with forward scattering)

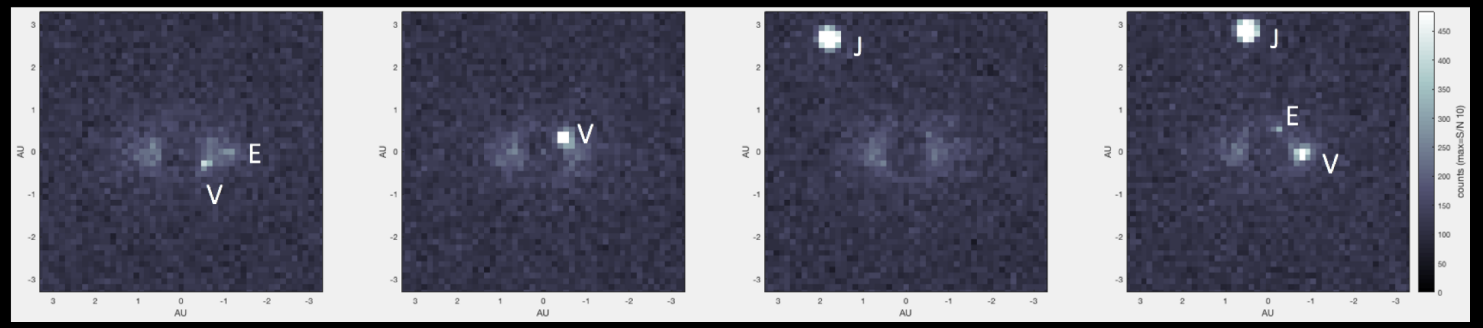
Noise: read noise, dark current, shot noise

[1]Astrophysical input data from The Haystacks Project: https://asd.gsfc.nasa.gov/projects/haystacks/haystacks.html

SISTER Examples



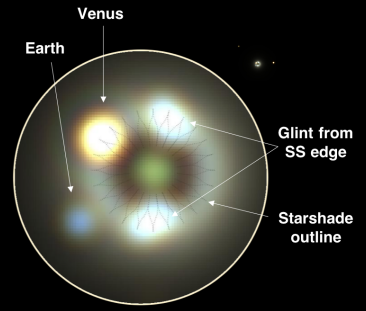
WFIRST STARSHADE RENDEZVOUS PROBE STUDY[1]

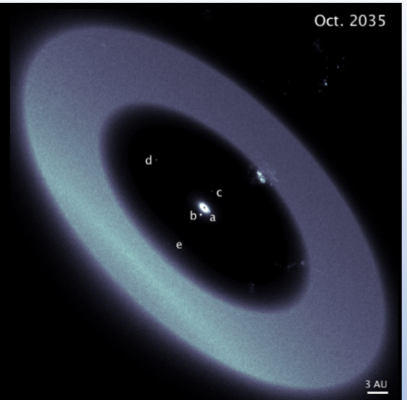


Four images of the imaging band 615-800 nm with 1 day integration time and realistic EMCCD detector readout[2] for our solar system as seen at 6 pc, with an inclination of 60°, and same exozodiacal light emission as the solar system. The color scale is linear and clipped at a signal to noise (S/N) of 10. Earth is observed with a S/N~3 in favorable phases. True albedos and Lambertian phase function were used.

HabEx

Our solar system as seen at 10 pc, face-on, for a starshade only HabEx 3.2 m mission with true color 400-700 nm

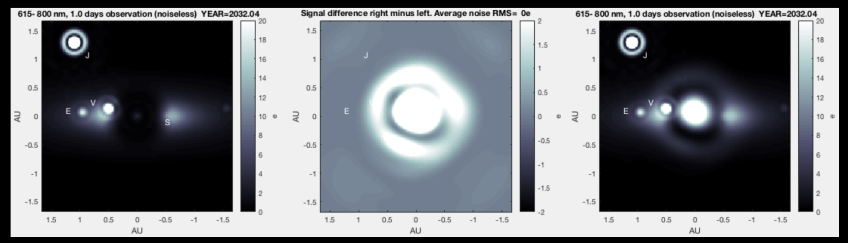




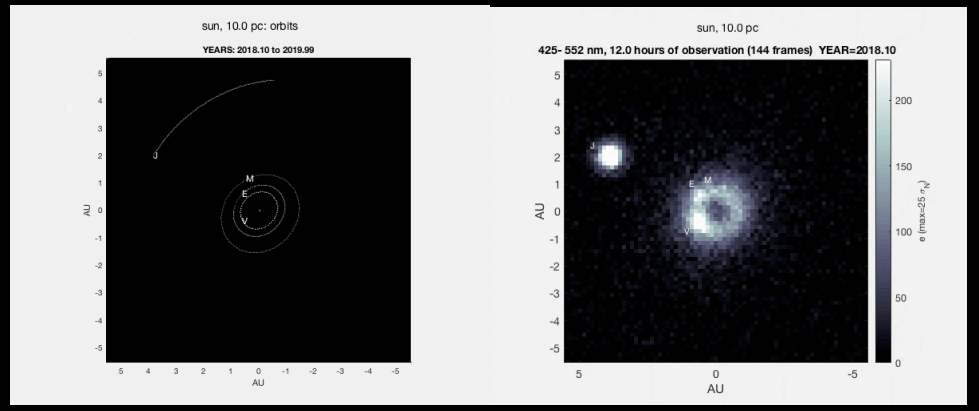
A solar system analog as seen from 5 pc by HabEx 4m + Starshade[7]
(a) an exoEarth
(b) a sub-Neptune
(c) Jupiter, (d) Saturn, (e) Neptune

- Inner dust belt (3x zodiacal dust within 1 AU)
- Outer dust belt (3x Kuiper belt extending 22 to 33 AU)
- FoV = 12x12 arcsec

NON-IDEAL STARSHADE: WFIRST REQUIREMENTS



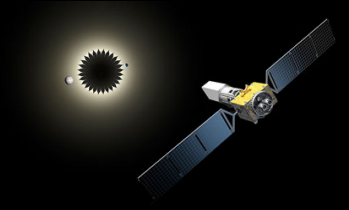
Solar system planets (true albedos) at 6 pc, 5x exo-zodi, and system inclination of 75°



(1) Starshade Rendezvous Probe Study Report, S. Seager, J. Kasdin, et al (2019) to be submitted.

(2) EMCCD software by P/ Morryssey JPL/Caltech 2019.

(3) *The Habitable Exoplanet Observatory (HabEx) Mission Concept Study Interim Report*; Gaudi, B. Scott; Seager, Sara; Mennesson, Bertrand, et al. 2018arXiv180909674G

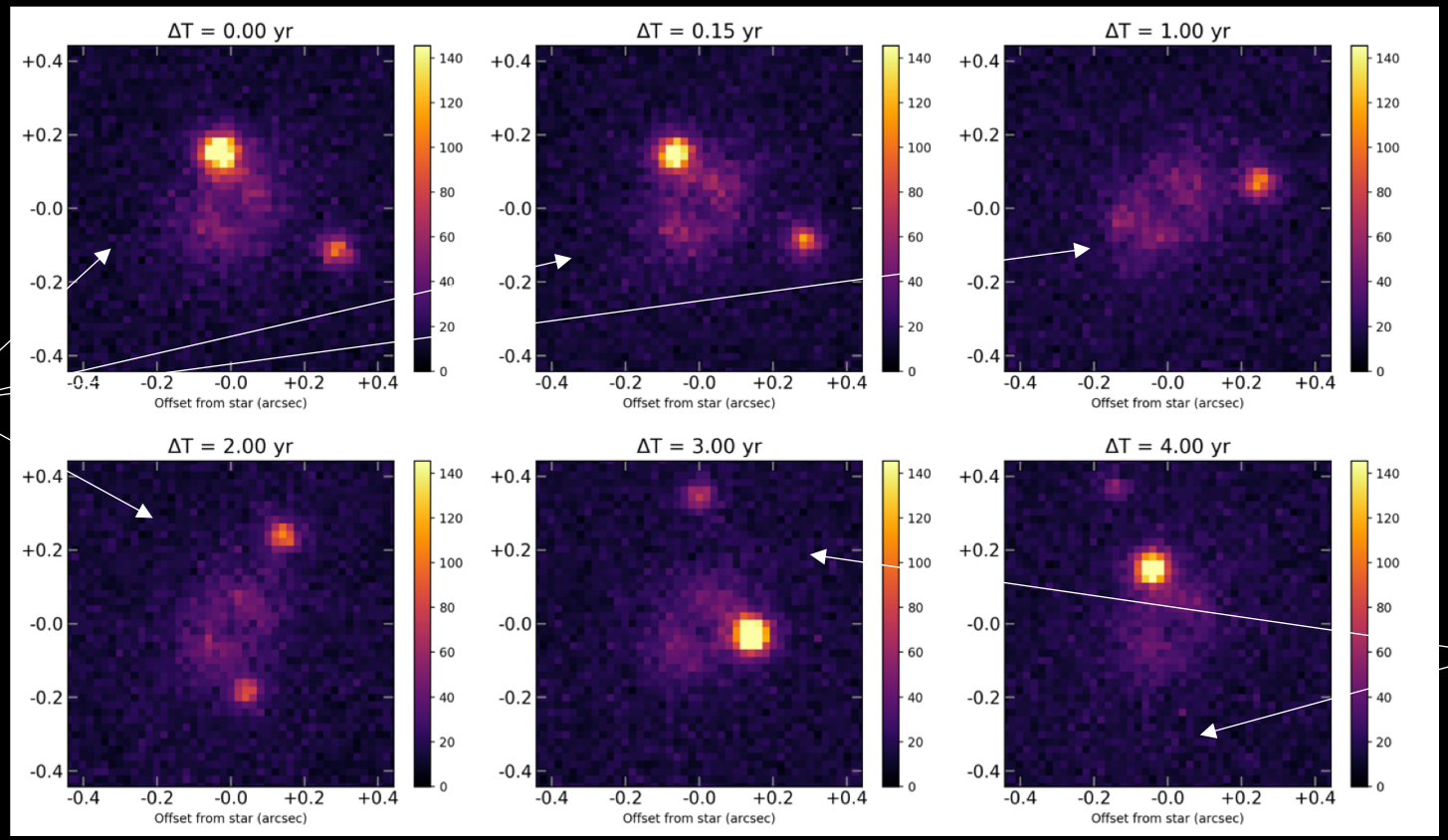


PUBLIC WFIRST CGI DATA CHALLENGE

Please contact turnbull.maggie@gmail.com, to participate

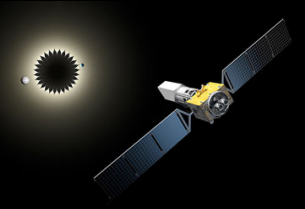
47 Uma planets b & c. Orbital and albedo determination challenge

CGI 24 hours of integration

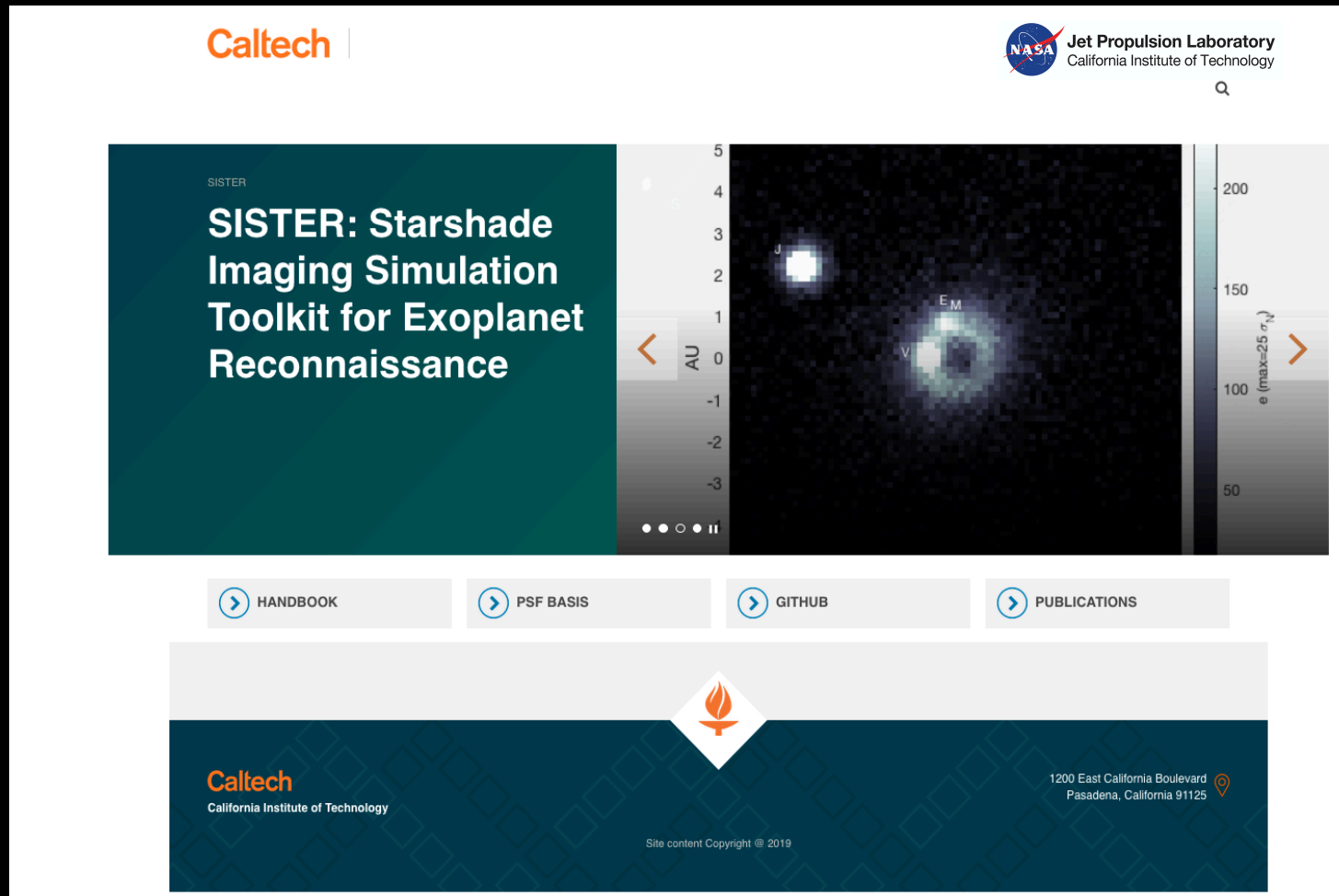


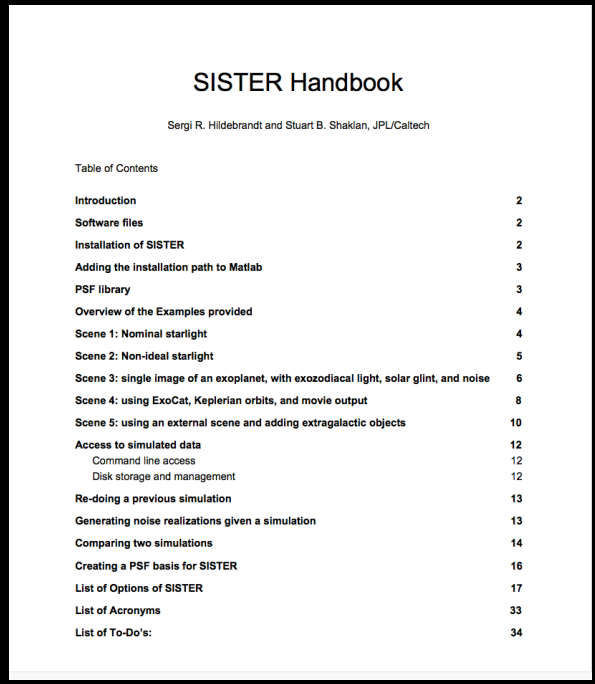
SS 6 hours of integration

SISTER PUBLIC RELEASE



April 12th 2019





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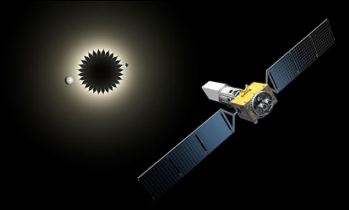
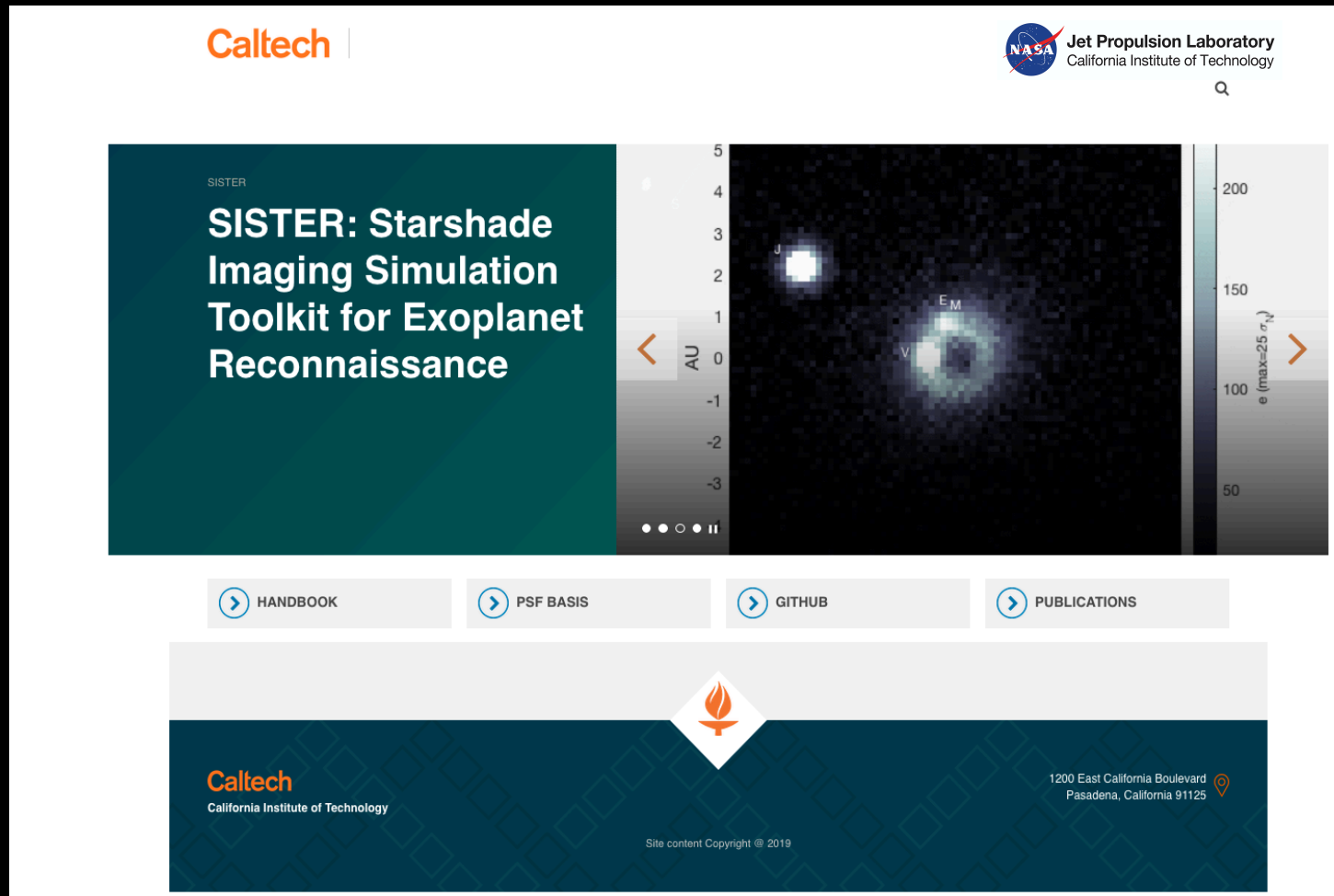
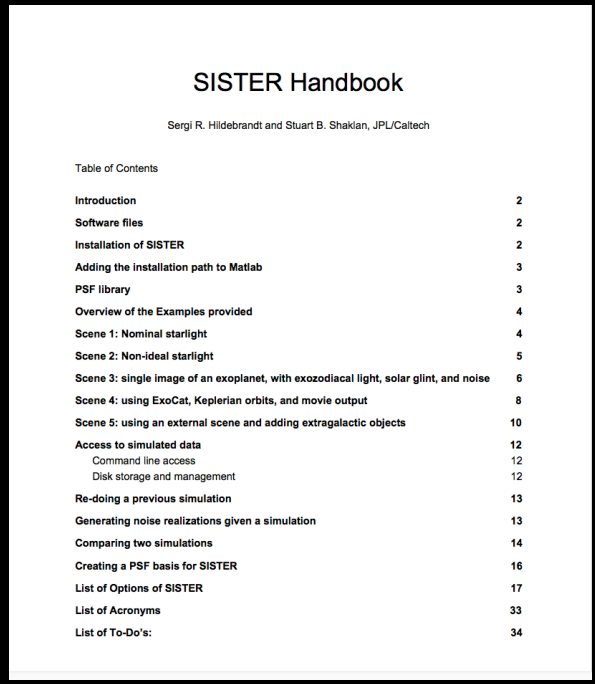
Stuart Shaklan, stuart.b.shaklan@jpl.nasa.gov

THANK YOU!

April 12th 2019







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